Expert System For Mine Burial Prediction

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LONG-TERM GOALS

An important factor in Mine Counter Measure (MCM) mission planning is knowledge of whether bottom-sitting mines are fully or partially buried beneath the marine sediment. The long-term goal of this project is to provide a mine burial prediction tool to enhance the capability for operational Navy MCM decision-making.

OBJECTIVES

The objective of the present effort is to synthesize the current state of knowledge on mine burial processes into a Mine Burial Expert System Model (MBESM). Incorporated into the MBESM are extant models for mine burial prediction as well as models currently under development in the ONR Mine Burial Prediction Program. The near term focus is on burial due to impact (essentially in muddy sediments) and scour (primarily in sandy sediments) and on burial in 'very shallow' and 'shallow water' coastal regimes, 3 m to 60 m depths.

APPROACH

Implementation of the MBESM is based on Bayesian probabilistic networks. A Bayesian network represents causal relationships among key variables as connections between "nodes" representing those variables. Connectivity between nodes represents knowledge about the extent to which one variable has a direct causal influence on any other. Causal influences are quantified by a conditional probability distribution (CPD) associated with the affected variable's node. These CPDs can be developed from field or laboratory data, output from deterministic physics-based models, expert's assessments, or any combination thereof. The advantage of Bayesian networks lies in their ability to model and reason about uncertainty, within the well-founded mathematical formalisms of probability theory and statistics. This supports decision making through the generation of quantitative, probabilistic measures of uncertainty and error, which can be directly used in cost/benefit decision analysis. For the current prototype implementation of the MBESM, the Bayesian network software Netica (NorSys, 2002) was used. This software allows an easy graphical exploration of the causal relationships. The core of the information incorporated into the Mine Burial Expert System is stored in Conditional Probability Tables (CPTs). Each CPT is developed using a Monte Carlo exercising of the physics-based models developed by the mine burial R&D community.

There is on-going research into modeling the behavior of mines with different shapes and densities during the initial deployment (fall through the water and impact with the sediment) as well as the

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subsequent burial processes including scour, bedform migration, sedimentation, and liquefaction. Additional information from the collation of reported field and laboratory data and the assessment of the applicability of these models based on expert interviews is also being utilized. Support for development of the MBESM at JHU/APL is provided by Sarah Rennie (project coastal scientist) and Steven Langs (Bayesian/AI expert). There are also ongoing interactions with numerous members of the mine burial research community regarding advanced burial modeling, and with Nathaniel Plant (NRL-SSC) and Peter Fleischer (NAVO) for implementation and transition of the MBESM for naval applications.

WORK COMPLETED

- The overall structure of the MBESM has been defined.
- The Bayesian framework has been implemented in a working prototype MBESM.
- Baseline burial models for impact (IMPACT28) and scour (HRWallingford/ DRAMBUIE) burial have used to generate core CPTs for impact and scour burial applicable to the 'very shallow' and 'shallow water' coastal regimes.
- Use of the MBESM has been demonstrated at example sites – e.g. the Norfolk shipping channel.
- Improved burial models and field data have been reviewed for incorporation into the MBESM, specifically: impact trajectory models (Yue, MIT, Chu, NPS), laboratory data on impact trajectories (Chu, NPS), field impact data (Valent, NRL-SSC), scour model (Inman/Jenkins, SIO) and laboratory scour data (Fernando, ASU).The scour prediction model developed by C. Friedrich (VIMS) has been evaluated for use in the MBESM (essentially a time dependent upgrade of the HRWallingford modelusing the Martha's Vineyard field experiment observations of Richardson and Traykovski).
- An interim empirical model has been developed for sediment shear strength that allows the use of NAVO database information directly in the impact burial model (Rennie and Brandt, 2002).
- Enhancement of the expert system analysis methodology to incorporate burial prediction error estimates is in progress.
- Guidance has been provided to Bennett (SEAPROBE) for his effort on the development of an improved characterization of marine geotechnical parameters for use in the MBESM.

RESULTS

The primary result of the past year's effort is the development of a working prototype version of the MBESM. This system incorporates the baseline impact (IMPACT28) and scour (HRWallingford/ DRAMBUIE) burial models. The performance of the improved burial models, when provided by the mine burial research community, will be compared to this baseline. This prototype model is currently under evaluation at NRL-SSC and NAVO. Figure 1 illustrates the prototype GUI developed for easy utilization of the MBESM. Sites where the environmental data are currently available are indicated on the map. The user can select the mine deployment conditions and the nature of the output format. Shown on the right of the figure are typical results – impact burial in the Norfolk shipping channel. The distribution of the sediment shear strength (the key parameter for impact burial) for this site is shown. The burial results are presented in two formats: the Navy standard MEDAL burial bins and a more refined burial distribution – 10 percentile bins.
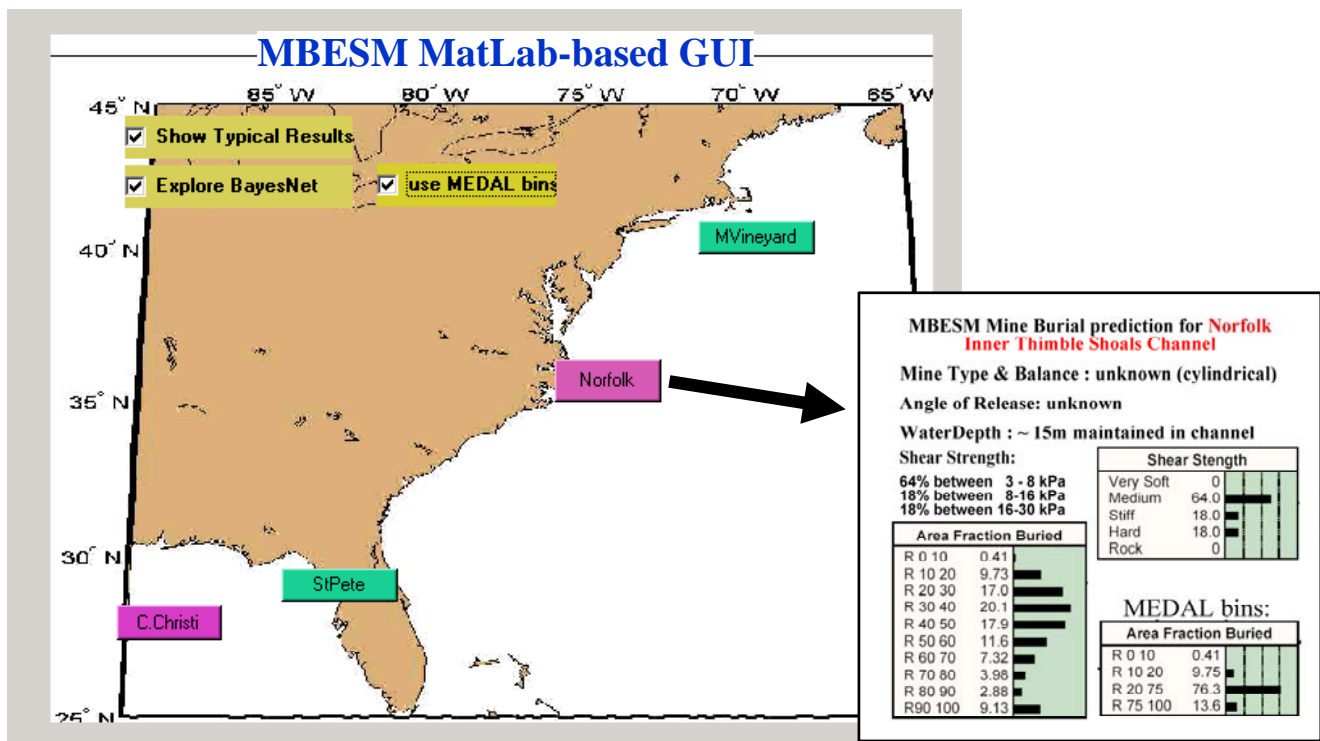
Figure 1. Illustration of the GUI interface for the Mine Burial Expert System Model (MBESM). The mine area fraction buried is proportional to the length of the bar, e.g. for the MEDAL bins this particular situation indicates that 76.3% of the mines would be buried between 20 and 75%.

IMPACT/APPLICATIONS

The goal of the proposed effort is to provide the MBESM in a form that can be used by NAVOCEANO and COMINEWARCOM for improved mine burial predicitons. Ultimately this Navy use will be implimented by incorporation of the MBESM into the Navy MCM Tactical Decision Aid package MEDAL. Toward this end (in addition to direct interactions with participants in the ONR Mine Burial Prediction Program) there are ongoing interactions with NAVOCEANO, NRL, CCS Panama City, CNO N752, COMINEWARCOM, and SAIC.

TRANSITIONS

As an intermediate step toward the Naval transition as discussed above, the current prototype, working version of the MBESM has been provided to Nathaniel Plant (NRL-SSC) and Peter Fleischer (NAVO) for review and evaluation.

RELATED PROJECTS

Results, i.e. advanced models of mine burial, from the ONR Mine Burial Prediction Program (http://www.mbp.unh.edu/) are to be incorporated into the MBESM.

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Rennie, S.E. and A. Brandt, 2002, "Marine Shear Strength Estimation for Impact Burial Modeling," JHU/APL 10 December 2002.
Norsys Software Corporation, 2003, http://www.norsys.com

PUBLICATIONS

Rennie, S. Brandt, A. "An Expert System Approach for Predicting Mine Burial," Proceedings 5th International Symposium on Technology and the Mine Problem, Naval Postgraduate School, Monterey, CA, 21-21 April 2002.